NOVEMBER 2018 Update

Small Cells Forecast

Major changes to the forecast this quarter include:

1. We have corrected an error in Table 1-7 of the previous FU1 forecast where the Carrier Outdoor CBRS shipments were offset by a year.

2. We have slightly raised our forecast of Residential Femtocells based on new information we have received as new market entrants in Asia is providing some incremental market opportunities for small cell vendors.

3. We have reduced the Residential Femtocells with Carrier Aggregation in the latter years in our forecast. While we expect some "high-end" residential small cells to incorporate Carrier Aggregation feature to possibly handle LAA and CBRS, the majority of the units will be plain single- or dual-carrier units used primarily for coverage.

4. We have picked up some new information on DRS shipments in China and have reduced our earlier growth trajectory in 2018 and 2019. While the overall indoor deployments will continue to increase, the rate of growth has been reduced to a more moderate pace. Meanwhile, we have significantly increased the share of4T4R MIMO configuration of Carrier Indoor units as all 5G DRS units announced will be operating at 4T4R in the C-band.

5. The Carrier Outdoor segment has been revised slightly up based on strong indications from NA infrastructure vendors and elsewhere of general RAN deployments. Moreover, we have received an input indicating additional Carrier Outdoor units shipped in 2017. The 2017 Carrier Outdoor figures have been updated to reflect this increase.

6. The Carrier Indoor segment is experiencing a very robust growth especially in China as the operators continue to densify and "digitize" indoor spaces with DRS deployments in preparation for 5G. We believe these indoor LTE deployments will eventually transition to 5G. Major tier 1 vendors have all announced 5G DRS units operating in the C-band (3.5 GHz), and we expect a small number of these units to be deployed in late 2019 with mass deployments starting in 2020 and extending to majority of indoor deployments in China during 2021-2023.

7. In North America, we observe robust operator activities around small cell deployments.

    a. Sprint continues to be active in small cell deployments, ranging from femtocells for residential and MagicBox for enterprise and select residential deployments. Meanwhile, the carrier continues to deploy strand-mount and Carrier Outdoor units to densify and

expand coverage. It remains to be seen how active this small cell strategy will remain in the combined T-Mobile/Sprint operation.

b. Verizon continues to expand its network capacity through a combination of spectrum carrier and small cell deployments. With over 1000 markets with LTE-Advanced features like carrier aggregation, 4x4 MIMO, etc., we believe Verizon will also take advantage of CBRS bands, and LAA in select areas, to increase network capacity. Please note that Verizon's 5G Home launch involving 5G millimeter wave base stations are Macro units in our definition (hence, they are not included in this Small Cells report).

c. AT&T is scheduled to launch LAA in 24 markets by the end of 2018. It has deployed LAA (in outdoor and some indoor) in 15 markets to date.

8. In China, the Carrier Indoor market which is dominated by the Distributed Radio Systems (DRS) systems including Huawei's Lampsite, Ericsson's Radio Dot, and ZTE's QCell is expected to grow at a more moderate rate in 2018-2019 than we had previously forecasted. The 5G DRS units are expected to gradually ramp up in second half of 2019 and the shipment is expected to pick up quickly in 2020 through 2023.

9. In Asia-Pacific, we are seeing infrastructure vendor partnerships to broaden product portfolio for the expanding Japan 5G market. Recent partnerships including Ericsson/Fujitsu and NEC/Samsung are some of the examples where domestic vendors are partnering with other major infrastructure vendors to provide end-to-end product portfolios to address the market needs. Facilities-based market entries of MVNOs in some markets are providing incremental market opportunities for small cell vendors.

10. In Southeast Asia, we continue to observe broad interests across different categories of small cells ranging from compact, high-power Carrier Outdoor units for network coverage in remote areas to wireless relay small cells (e.g., Airspan's MagicBox, Huawei's Libero).

11. In Europe, some operators are selectively deploying small cells in select residential and enterprise segments to expand coverage and capacity. While most major operators seem inclined to wait out the initial 5G "waves" in North America and China, many are trialing and selectively deploying gears from new vendors. The recent OpenRAN RFI from Vodafone and Telefonica provides glimpse of new players making inroads here.

12. While the CBRS market momentum continues apace in the USA, the commercial service launch is not expected until the beginning of 2019 when the FCC is expected to finally approve SAS operation after the Initial Commercial Deployments (ICDs) are approved. While the fixed wireless access and Private LTE applications are expected to lead the commercial launch, the main mobile use is expected to earnestly ramp in first half of 2020 when PAL license auction is expected. Meanwhile, CBRS small cells will be shipped during 2018 and 2019 as operators and enterprises launch services on GAA throughout 2019.

13. We are seeing a robust LAA adoption in North America, namely Verizon, T-Mobile, and AT&T. Sprint is expected to continue its network expansion via small cells and macro site expansion with its abundant treasure trove of 2.5 GHz spectrum. The early LAA results show dramatic user throughput speed increases. We believe operators in other regions will also adopt LAA in the coming years.

14. Overall, the Small Cells market is growing at a robust growth in 2018 especially in the Carrier Indoor segment with heavy indoor deployments of DRS units in China. Excluding residential femtocell shipments, the overall small cell shipments is expected to grow 25% year-over-year in 2018 with revenue growing 14% year-over-year. The 5G small cell uptake is expected to ramp up in 2020 as Chinese operators deploy 5G DRS units en masse in the C-band.